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**Automated Identification of Oceanic Fronts for
Operational Generation of Potential Fishing Zone (PFZ)
Advisories**

by

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Abstract (100 words)

PFZs, are essentially the frontal structures as identified from the satellite images of Sea Surface Temperature (SST) and chlorophyll concentration. These regions are known for fish aggregation and provide cost-effectiveness in offshore fishing operations. Subjective identification of fronts may lead to human-errors, non-negotiable beyond a limit. To overcome this, we propose utilization of tools that help automated identification of the frontal structures. This approach not only removes the errors, but also helps shorten the time period of the operational process-chain.

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ABSTRACT

One of the flagship services of the Indian National Centre for Ocean Information Services (INCOIS) is Potential Fishing Zone (PFZ) advisories, which are essentially the frontal structures as identified from the satellite images of Sea Surface Temperature (SST) and chlorophyll concentration. These regions are known for fish aggregation and provide cost-effectiveness in offshore fishing operations. Subjective identification of fronts may lead to human-errors, non-negotiable beyond a limit. To overcome this, we propose utilization of tools that help automated identification of the frontal structures. This approach not only removes the errors, but also helps shorten the operational process-chain, which becomes more important as the products and services rise in the future.

1. Introduction

1.1 Potential Fishing Zones

The Marine Fishery Advisory Services (MFAS) programme of the Indian National Centre for Ocean Information Services (INCOIS) provides information to the fishermen about potential locations of fish aggregations as an advisory. For this, satellite images of Sea Surface Temperature (SST) and chlorophyll are being used. The science behind food availability has been pursued effectively in last few decades, for Indian waters and elsewhere (Solanki et. al. 2001a, 2001b, 2003, 2005, 2008; Nayak et. al., 2003; Zainuddin et al., 2004; Dwivedi et. al. 2005). Moreover, validation experiments have shown that such prior information makes fishing operation more economically viable by saving of fuel and time. (Choudhury et al., 2007; Tummala et al., 2008, Das et al, 2010; Pillai. V.N, 2010, Deshpande et al 2011, Nammalwar et.al. 2013, S. Subramanian, 2014). The service also contributes in improving Indian's carbon footprint by means of reducing emissions from boat engines (NAIP AR 2011-12, E. Vivekanandan et.al. 2013, Shubhadeep Ghosh et.al. 2014, Renju Ravi, 2014). Productivity that induces fish aggregation was first known to be associated with the temperature frontal zones (Santos, 2006; Zainuddin et al., 2006; Kumari B, 2009; Onitsuka et al., 2009; Tummala et al., 2009; Anukul et al., 2010; Fiedland et al, 2012).

1.2 Manual identification of the fronts

For an operational service, the identification of the productive oceanic fronts needs utmost care and supervision to ensure that the final advisory being conveyed to the users is reliable. Since its inception, the PFZs are being identified manually. The retrieval of SST and chlorophyll parameters from satellite imagery was done through image processing and GIS techniques and applying relevant algorithms. Depending on the data source and image processing level, the sequence and steps for retrieval of the parameters may vary. The retrieved final product is used for identification of frontal structures

Followed by this is the manual process where a trained expert identifies the frontal structure (e.g. interface of warmer and colder water masses) and traces with the help of tool within the GIS (Geographic Information System) software. This step is highly critical in the generation process of fishery advisories and needs utmost care by the trained personnel. In terms of GIS and image processing techniques, all the satellite products are in the form of raster images and the traced fronts will be in the form of a vector. The delineation of fish aggregation zones i.e. PFZ advisories from the satellite data has different approaches. One approach is to identify fronts from various images (from various satellites and passes and various parameters) separately and later vectors can be superimposed to identify the common features. Other approach is to trace vector on one image and superimpose on another image to eliminate non-recurring features, until all the intended images are not utilised. For example: the thermal boundaries and upwelling regions identified from the SST parameter can be overlaid on Chlorophyll imagery for identification of common fronts where physical and biological signature co-relate. Although this approach has full control and supervision of the expert, the process is time consuming (ranging somewhere between 25-50 minutes, depending on the data available) as well as has inherent probability of manual error.

The latter can be understood from an inter-comparison exercise (called, PFZ cognition exercise) that was carried out to understand how manual identification of PFZ may vary even among the rigorously trained personnel (Fig. 1). A pool of five personnel participated in the exercise, who were isolated and were provided with same set of satellite images. The personnel were then asked to identify PFZs as a part of the operational process. The PFZ vectors generated by the individuals were then superimposed. Though all the features that were identified were the probable fish aggregation zones; for the cognition exercise, only the percentage of the features that every person identified was used. Where at least three out of five personnel have identified a feature, it was counted as high agreement, whereas two or

less have identified a feature it was counted as low agreement. Then, for each individual, percentage of features with high and low agreements was derived. As it is evident from Fig. 1 that the ability to identify the feature successfully varied between 60-85%, with an average of 69% (black threshold line).

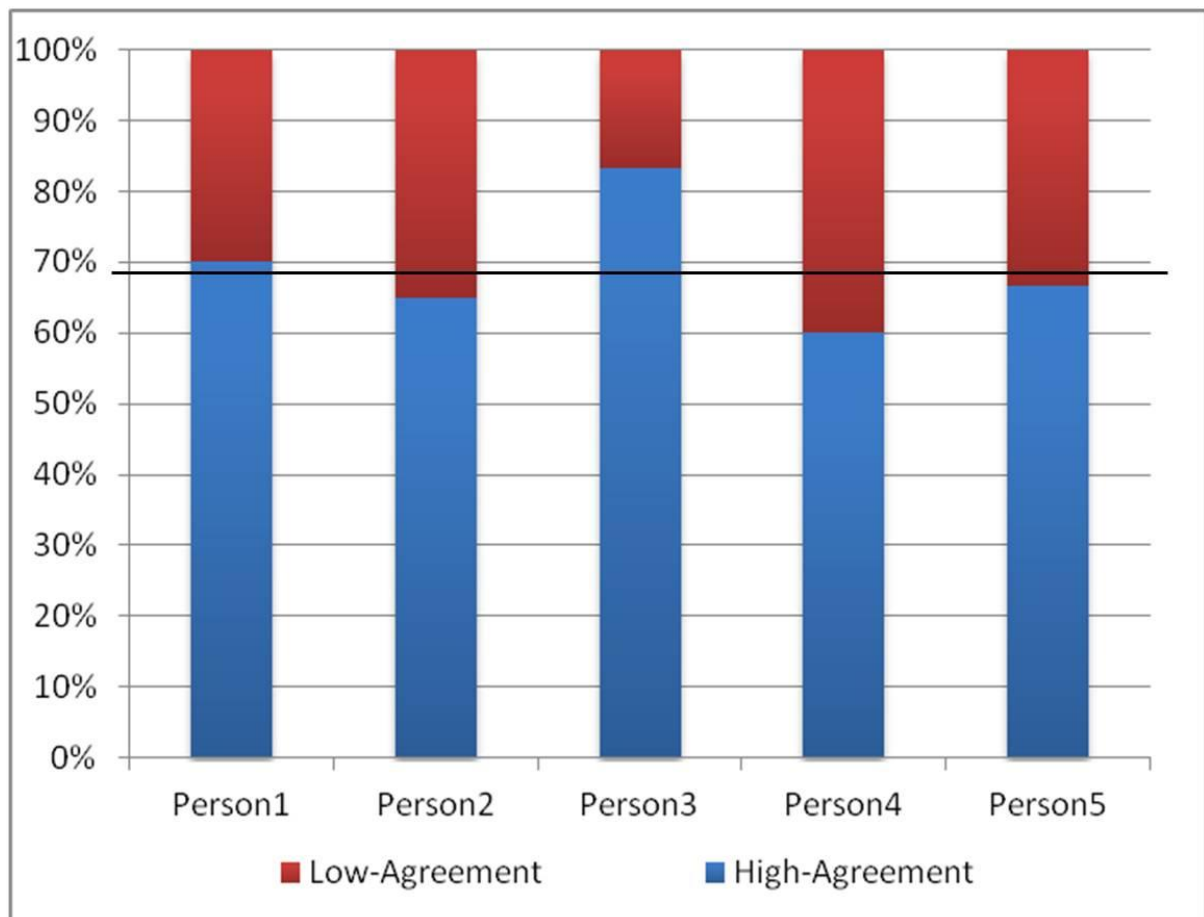


Fig.1 Outcome of the PFZ cognition exercise showing percent of matching PFZs. Black line indicates average agreement (69%) of PFZ features among all the test group.

It is known that satellite data quality is affected by factors such as presence of cloud-cover. It was observed that in case of clear skies, every individual identified all the prominent features in the chlorophyll and SST satellite images, equally. This underlines that under normal condition (data availability and presence of prominent features) the cognition levels of

personnel were satisfactory and it does not affect to the result quality. However, it was observed that in case of satellite images with cloud-cover and other cases - where pixel-data was partially distorted (spatio-spectral reasons inherent with remote sensing technology such as edge of the image) - moderate variation was observed in perception at individual-level. The same was also observed where features were not much prominent. Being the fact that this falls under domain of human cognitive limitations, it cannot be fully eliminated in present approach. In order to minimize the probability of the occurrence of same, adaptation of mathematical/algorithmic expression methods for automatic detection of fronts and productive areas instead of manual interpretation technique is advisable.

1.3 Automated Identification of the fronts

With the advent of satellite oceanography and ever increasing inventory of remote sensing data in last few decades, attempts have been made to automate image processing as much as possible, so that researchers can invest their time in research instead. Oceanic fronts have been of interest to larger group of oceanographers including those who study physical, biogeochemical and biological properties. Thus, tools have been developed to automated identification of oceanic fronts as well and some notable ones are by Cayula and Cornillon, (1992 and 1995); and that by Belkin and O'Reilly (2009). These operate by employing moving window average over the pixels (e.g. of 3x3 pixels) and assigning average value to the centre pixel. In this way, when this moving window scans a frontal zones, it detects slope in the pixel values and amplifies the signal. This approach works best where the original satellite image has strong bi-modal histogram characteristics, i.e. when the front is strong. Thus, in order to identify strong fronts (which are known for their persistency) such algorithms work best. However, by changing the slope threshold value, these algorithms can identify moderately strong or weaker fronts as well. The user have to calibrate the threshold to obtain optimum range that identify maximum fronts with minimum possible noise.

2. Data and Methods

2.1 Remotely sensed Sea Surface Temperature (SST) data

SST data in the form of daily satellite passes are being received from INCOIS ground station. The data is derived from AVHRR (Advanced Very High Resolution Radiometer) sensor onboard NOAA series (N-18, N-19) and ESA satellites (MetOp-1 & MetOp-2). The satellites provide data at spatial resolution of approx 1.1 km (≈ 1100 m).

2.2 Remotely sensed chlorophyll data

Satellite chlorophyll data is being received from Indian satellite Oceansat-2's OCM (Ocean Colour Monitor) sensor at 360m spatial resolution with repeativity of two days. Additionally, data from NASA (National Aeronautics and Space Administration, USA) missions such as MODIS (Moderate-resolution Imaging Spectroradiometer)-Aqua and NPP-VIIRS (National Polar-orbiting Partnership - Visible Infrared Imaging Radiometer Suite) are being obtained through INCOIS ground station (depending on antenna availability) and through NASA GSFC (Goddard Space Flight Centre) OceanColor portal (<https://oceancolor.gsfc.nasa.gov>) via the Indian Ocean component of the Chlorophyll Global Integrated Network (ChloroGIN - IO) Project, node at INCOIS (<http://www.incois.gov.in/portal/ChloroGIN>).

2.3 Geospatial model

Out of aforementioned algorithms, the one proposed by Cayula and Cornillon, (1992) suits best for the operational generation of PFZ, due to its simplicity and requirement of a single image at a time. The algorithm is known as Single Image Edge Detection (SIED) and is available as an open source tool for ESRI's ArcGIS environment, which MFAS operational processing chain employs (Roberts et al., 2010).

3. Product

The SIED output will be in the form of raster pixel and visually edgy. In order to realize the real-world curvature of the fronts and for better understanding of resultant PFZ by fishermen,

few steps are required. First, the pixel boxes are converted to a line by using “Thin” tool from ArcGIS in-built toolbox named ‘Spatial Analyst’. This raster output is then converted into a polyline vector; and appropriate masks for cloud, land-proximity, restricted fishing zones, Indian EEZ boundary, etc. may be applied as required. Based on the bulk of satellite data available, this can be done with every individual images or to a combined output from multiple satellite images.

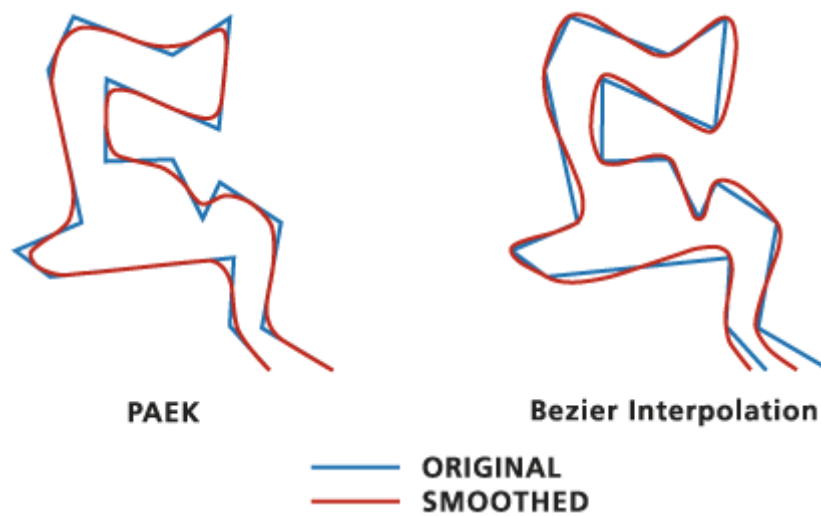


Fig.2 Conceptual diagram of .smoothing approaches (Courtesy: ESRI)

After this, the output is yet in the zigzagged form. ArcGIS toolbox ‘Cartography’ has tool named ‘Smooth Line’, which provides user two approaches to choose from (Fig. 2). We opted for PAEK (Polynomial Approximation with Exponential Kernel) which provides better control by giving the user an opportunity to define tolerance (threshold) to the curvature. The conceptual model summarizing these steps and final output (against one original satellite image as an example) have been shown in Fig. 3 and Fig. 4, respectively. Here, note that there are some minute (almost noise-like) features also retained. As aforementioned depending on the operational requirement, a threshold for the identification of the features can be defined.

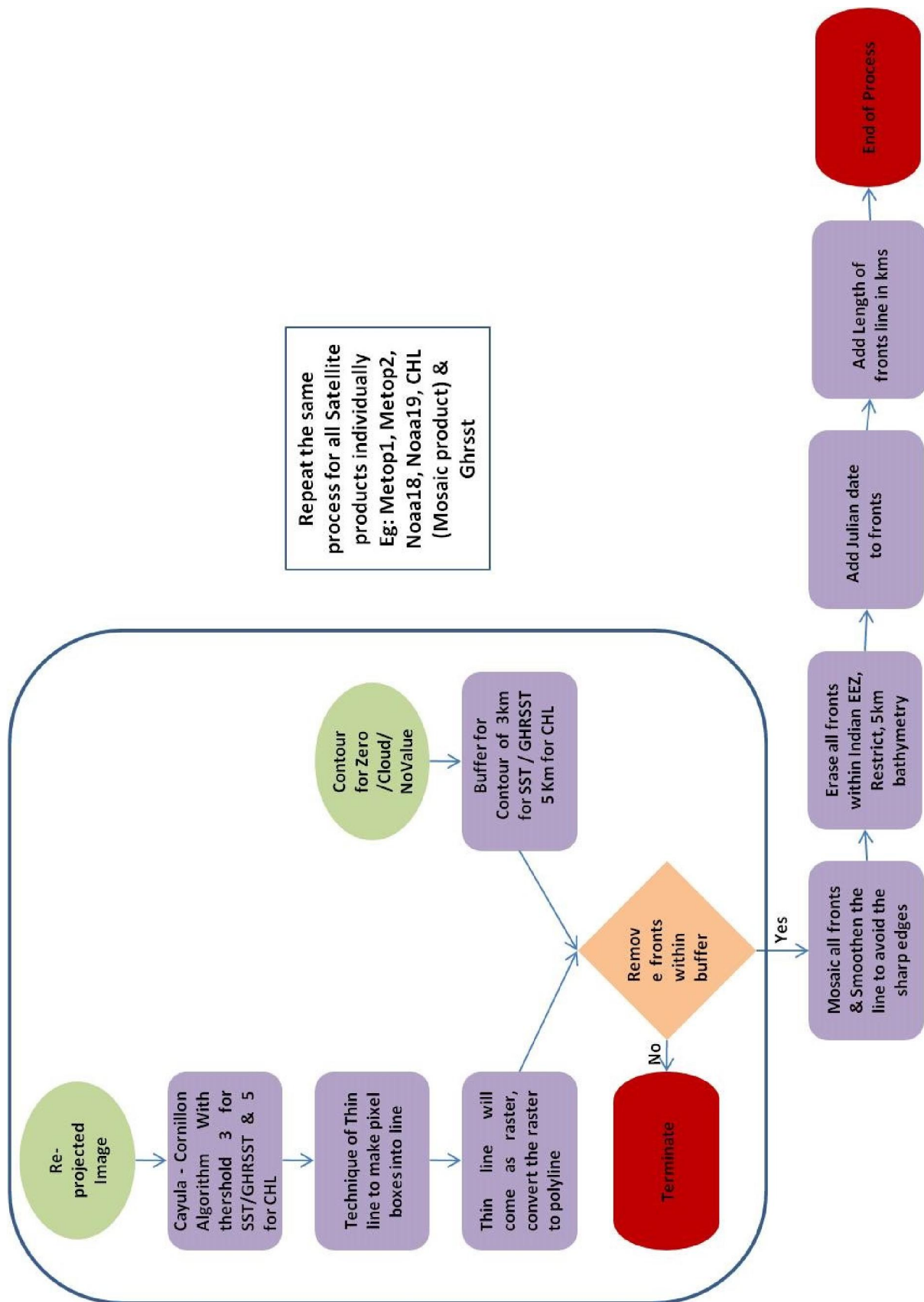


Fig.3 Concept approach of automated frontal identification for fish aggregation

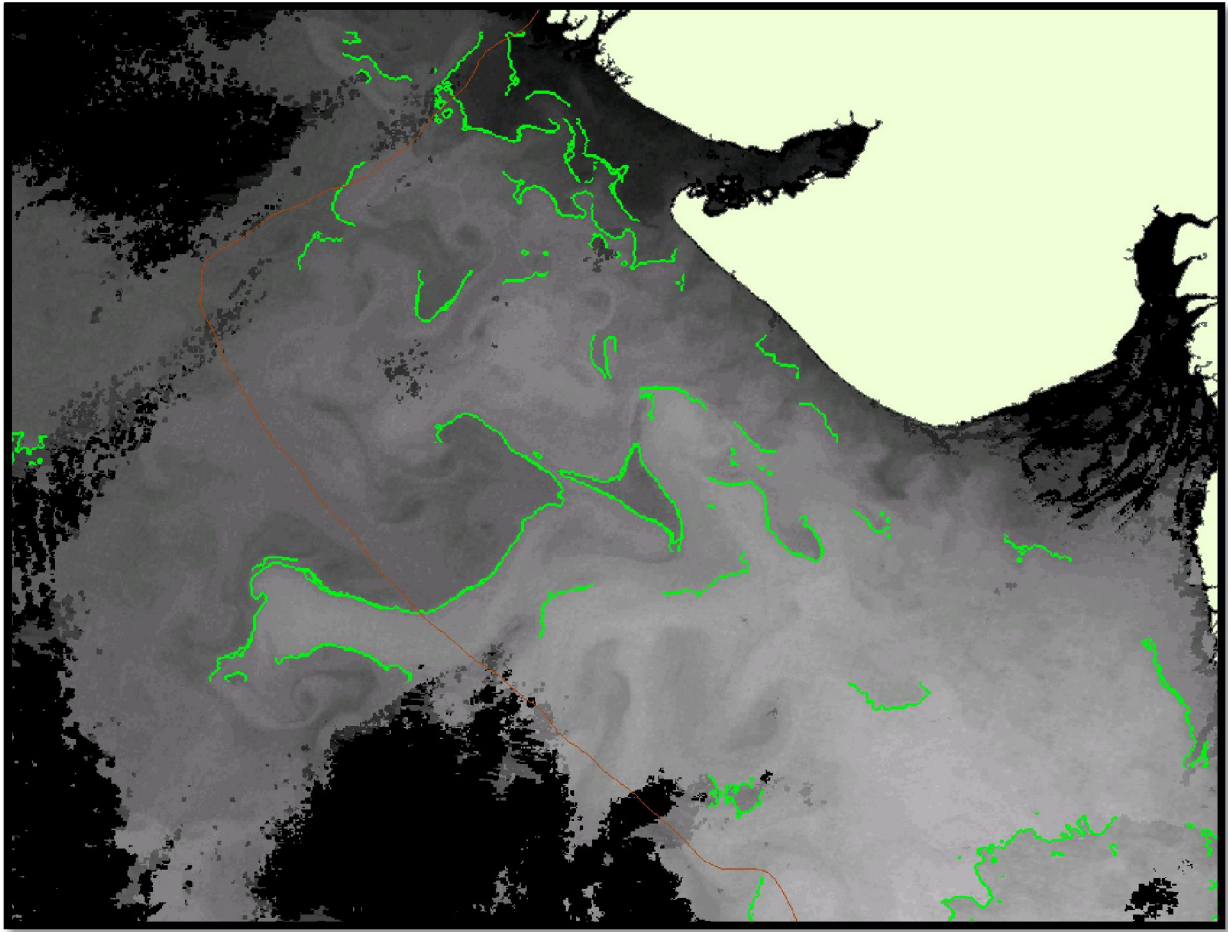


Fig.4 An example output of the automated front detection model overlaid to an SST image.

We have observed that for remotely sensed AVHRR-based SST data, 0.3°C threshold (between neighbouring pixels) applied to 3×3 pixel window provides best possible feature to noise ratio. The same for satellite chlorophyll is found to be optimum at 0.5 mg m^{-3} threshold for the larger 5×5 pixel window. Further threshold for feature length can be defined in a post-processing step; so that all the smaller features (more likely to be noise than the fronts) below this threshold can be eliminated to highlight the prominent and large-scale features.

4. Conclusion

In this report, we highlight the importance of automated identification of the oceanic fronts for operational potential fish aggregation advisory service. We demonstrate with a control exercise that even in the best-practise and training scenario, subjective interpretation of

satellite data has inherent limitation. To address this, we propose this geospatial approach that offers identification of fronts objectively and is faster (time-saving of minimum 10-15 minute per satellite image) in comparison to the manual operation.

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